Present Status and Future Prospects of Sea Cucumber Breeding and Culture in India

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Introduction

The holothurians or sea cucumbers are commercial echinoderms, which are exclusively marine in their habitat. Holothurians inhabit different depths of the ocean as well as different habitats such as rocky shores, sandy beaches, muddy flats, coral reefs and mangrove swamps. Out of 154 genera and 1,150 species recorded in the world, 62 genera and 160 species are available in India; among them, 88 are recorded in Andaman and Nicobar Islands, 39 in the Gulf of Mannar and 32 in Lakshadweep.

Economic Value

Holothurians are exploited commercially, for the raw body wall or viscera, but mostly for the processed dry product called 'beche-de-mer'. The Chinese are the traditional consumers, and Japanese, Koreans, Melanesians, Micronesians, Polynesians and African people also consume 'beche-de-mer' in significant ways and quantities. In traditional Chinese medicines, the sea cucumbers are used for treating weakness, impotency, debility of the aged, constipation due to intestinal dryness and frequent urination. Recent findings indicated their potential role in the biomedical research, as a rich source of polysaccharides like chondroitin sulphate and glucosamine and other bioactive substances with anti-inflammatory, antitumour and fungicidal activity. Apart from these nutritional and therapeutic values, the sea cucumbers are important components of the food chain, because they play an important role as deposit and suspension feeders. They are often called the earthworms of the sea, because they are responsible for extensive shifting and mixing of substrate and recycling of detrital matter.

Fishery and Trade Status

Sea cucumbers are fished all over the world, particularly in tropical regions. The total global catch of sea cucumbers is in the order of 100,000 t of live animals annually. The leading exporters were Indonesia, the Philippines, Fiji Islands, Japan, Madagascar, Papua New Guinea, Solomon Islands, Thailand and the USA. Due to high demand, ease of harvesting and low cost production technique, the sea cucumber has developed rapidly (Conand 2004).

Indian Beche-de-mer Industry

In India, the 'beche-de-mer' industry was introduced by the Chinese more than 1,000 years ago. It is essentially a cottage industry based in rural areas needing little investment.

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The industry consists of the fishermen, who are divers, the processors who act as middlemen and the exporters. Though the sea cucumbers are distributed in Lakshadweep, Andaman and Nicobar Islands and the Gulf of Kutch, the processing of sea cucumbers was going on only in the Gulf of Mannar (GOM), and it played as an important source of income for about 50,000 poor fisherfolk along this area. The cost of the sea cucumber varies with the species and among the seven commercial species; *H. scabra* was the highly priced species followed by *H. spinifera*. The processed 'beche-de-mer' was exported mainly to Singapore from India, because of the lack of domestic 'beche-de-mer' markets. During 1996–1997, India exported 70 metric tonnes of 'beche-de-mer', which has decreased to 3.81 metric tonnes during 2001 (Hong Kong SAR import statistics).

Statutory Regulations

Over-exploitation of sea cucumber resources has caused local extinction of breeding population of some species and the collapse of other stocks in some countries. Owing to the dramatic declining of catch and size of the specimens fished, the Ministry of Environment and Forests, Government of India, imposed a ban on sea cucumbers in 1982, and accordingly fishing of sea cucumber of less than 8 cm was prohibited. The Ministry imposed another ban in June 2001 on sea cucumber fishery and listed the holothurians as protected animals along with 50 other marine species under the Indian Wildlife Protection Act, 1972, which has caused severe impact on the livelihood of several thousands of fishermen populations along the Gulf of Mannar and Palk Bay, who subsist on the fishery of this species, and also reduced the foreign exchange too.

The releasing of hatchery-produced juveniles of commercial sea cucumber species to their natural habitat, a process called restoration, restocking or reseeding, is gaining momentum worldwide, as the only way to replenish the depleted stock of holothurians. The Central Marine Fisheries Research Institute has given subtle importance on the conservation aspects of this fragile resources by implementing projects on the development of seed production techniques of commercial sea cucumbers and succeeded in developing seed production techniques of commercial holothurians like *Holothuria scabra* (Fig. 1a) in 1988 and *H. spinifera* (Fig. 1b) in 2001 for the first time in the world. *Holothuria scabra* commonly called sandfish is one of the most commercially valuable tropical species of sea cucumber with a wide distribution throughout Indo-Pacific areas. The A-grade beche-de-mer processed from sandfish commands some of the highest price on the international market. Since the mass production of juvenile *H. scabra* through hatchery system has been proved, it is being considered as an ideal

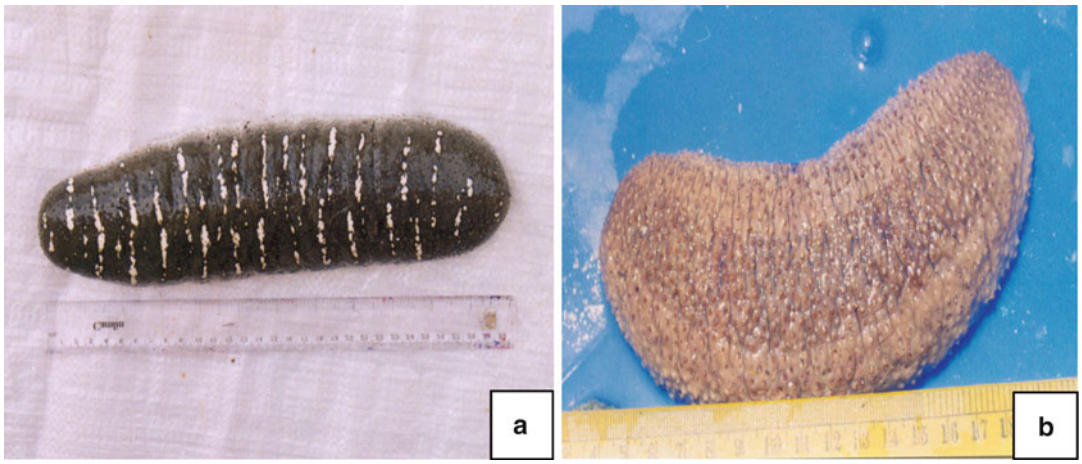

Fig. 1 Brood stock of holothurians: (**a**) *Holothuria scabra* and (**b**) *H. spinifera*

candidate for stock enhancement programme in many countries. *H. spinifera*, the second major contributor to the beche-de-mer industry along the south-east coast of India, is already declared as an endangered species in China, and its availability is not yet confirmed in many places of its earlier distribution; hence, sea ranching of its hatchery-produced seed to the natural habitat will have greater importance. Through continuous research effort in the breeding and hatchery aspects of these two species, several improvements have been made in the holothurian hatchery system (Asha 2005; James et al. 1999).

Hatchery Operations

1. *Brood stock collections and management*

The brood stock of the sea cucumbers has been collected from the wild during the breeding season. The quality and liveliness of the specimens are best in those collected by skin divers; they never developed any disease and also often yielded effective spawning. Hence, it can be recommended that the skin diving specimens are best for hatchery operations.

The breeding attempt were carried out during two spawning peaks, i.e. during the major breeding peaks (March–May and October–December), in the case of *H. scabra* and from November to March in the case of *H. spinifera*; hence, the brooders have to be collected prior to the spawning peaks. Care should be taken for the storage of good-quality filtered sea water with adequate salinity. The brood stock collected by skin divers can be acclimatized in the hatchery for 2 weeks before subjecting them for spawning induction by maintaining in a 1 t tank with 6 in. thickness of fine beach sand in a continuous system with a daily exchange of rearing medium, and the brooders can be fed with *Sargassum* spp. powder at 0.5 g/500 l^{-1} (James et al. 1988, 1994).

Spawning Induction

The brood stock was induced to spawn by several techniques. Addition of feed made of rice bran, *Sargassum* spp. and soya bean powder (2:1:0.5) at 50–100 g^{-1} 500 l^{-1} is found to be very effective in the case of *H. scabra* and *H. spinifera* (Asha and Muthiah 2002). On one occasion, the sudden changes in salinity caused effective spawning among the brooders. The egg suspension from an eviscerated female also induced spawning successfully on one occasion. Instead of going for thermal shock, a combination of cold shock followed by hot shock (±5 °C) is also found to be more effective in *H. scabra*. Since it is difficult to determine the sex of sea cucumbers externally, it is advisable to collect 30–40 specimens having a length and live weight ranging from 20–30 cm and 300–500 g. It is advisable to maintain 15 brooders 500^{-1}.

Larval Rearing

High sperm density will affect the fertilization; hence, care should be taken to filter out the fertilized eggs. Experiment proved that stocking densities of 0.5 ml^{-1} for the eggs and 1 ml^{-1} for the larvae are the optimum hatching and larval rearing conditions (Asha and Diwakar 2013). The fertilized eggs (Fig. 2a) and larvae can be stocked in sterilized sea water filtered through 1 μm with mild aeration to get the effective hatching and development (Asha and Muthiah 2002). The chronological developmental stages with the details of various larval stages up to pentactula with the time of occurrence and mean size are given in Table 1.

1. *Early development*

After fertilization, the first polar body appears within 20–30 min. The first cleavage takes place after 15 min. In 3 h, blastula is fully formed. After 24 h, the gastrula (Fig. 2b) is fully developed, which is oval in shape and motile. After 48 h, early auricularia appears.

2. *Auricularia larva*

Early auricularia (Fig. 2c) is developed within 48 h, which passed through the mid- and later stages within 10 days. It is slipper shaped, transparent and pelagic in habit. It has a preoral loop anteriorly and anal loop posteriorly, which helps in locomotion. The digestive tract consists of mouth, pharynx and sacciform stomach.

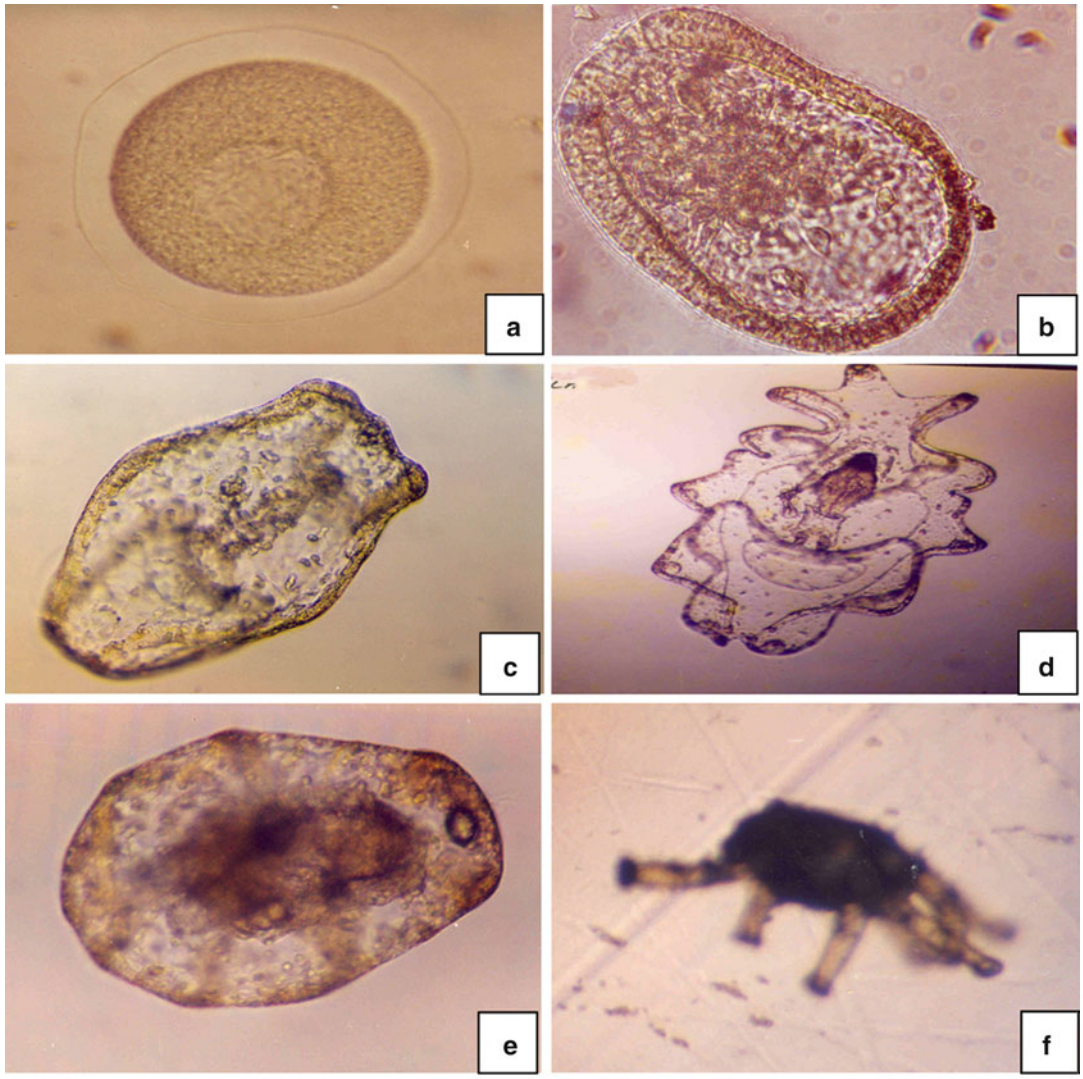

Fig. 2 Developmental stages of holothurians: (**a**) Fertilized egg, (**b**) gastrula, (**c**) early auricularia, (**d**) late auricularia, (**e**) doliolaria and (**f**) pentactula

Table 1 Time after fertilization for the different development stages of holothurians

Development stag	Time after fertilization	Mean size
Blastula	3 h	_
Gastrula	24 h	265.4 ± 6.06 μm
Auricularia (early)	2 days	489 ±14.1 μm
Auricularia (late)	10 days	1.1 mm
Doliolaria	10–12 days	468 ± 23.3 μm
Pentactula	13–15 days	330 ±16.7 μm
Early juveniles	20 days	1 mm
Juveniles	90 days	40 mm

On the tenth day, the late auricularia larva (Fig. 2d) metamorphoses to doliolaria larva.

3. *Doliolaria larva*

The doliolaria is barrel shaped, free floating and in a nonfeeding stage with five bands around the body (Fig. 2e). This stage will last for 2–3 days, and subsequently they metamorphosed to the creeping stage known as pentactula.

4. *Pentactula larva*

The pentactula is tubular with five tentacles at the anterior end and with a single tube foot at the posterior end (Fig. 2f) which helps in the locomotion of the larva. The pentactulae creep over the sides and bottom of the tank.

Larval Feeding

The appropriate concentration of feed is important for the successful larval rearing. The feeding schedule has to be determined by the larval healthiness. The early auricularia for the first 3 days can be fed at 2×10^4 which can be slowly raised to 3×10^4 in the mid-stage to 4×10^4 in the later stage (Asha 2004). The larvae are found to survive well when fed by *Isochrysis galbana* but grow well when fed by *Chaetoceros calcitrans*; hence, a mixture of these two (1:1) is found to be an ideal feed for the auricularia larvae for 10 days (Asha and Muthiah 2006). By periodic assessment of larval growth rate, the feeding regime can be adjusted so that the auricularia larval survival rate can be improved even up to 80–90 %. No feed has to be given to the doliolaria larvae. The doliolaria larvae have to maintain at 2 ml^{-1} in a flow-through system in which equal quantity of water is allowed to let in and let out. The water temperature 28–32 °C, pH 7.8 and salinity 35 ppt are the suitable environmental condition for the metamorphoses and settlement of the larvae (Asha and Muthiah 2005; Asha et al. 2011).

Settlement

The doliolaria can be induced to settle by the daily addition of powdered algae Algamac at a concentration of 0.5 g 500 L^{-1}, which will act as an inducer for the doliolaria to settle and also will serve as a food source for the newly settled pentactulae. The newly settled pentactulae can continue to feed Algamac for 1 month with slowly raising the concentration from 0.5 g to 1 g 500^{-1} (Asha and Muthiah 2007). The periodic thinning out of the pentactulae to reduce the stocking density is found to improve the growth rate (Sui et al. 1986).

Nursery Rearing

One-month-old juveniles of sea cucumbers of both H. *scabra* and H. *spinifera* (Figs. 3a and 4a) were given *Sargassum* spp. extract (<40 μm) for 1 month in a bare tank. When the

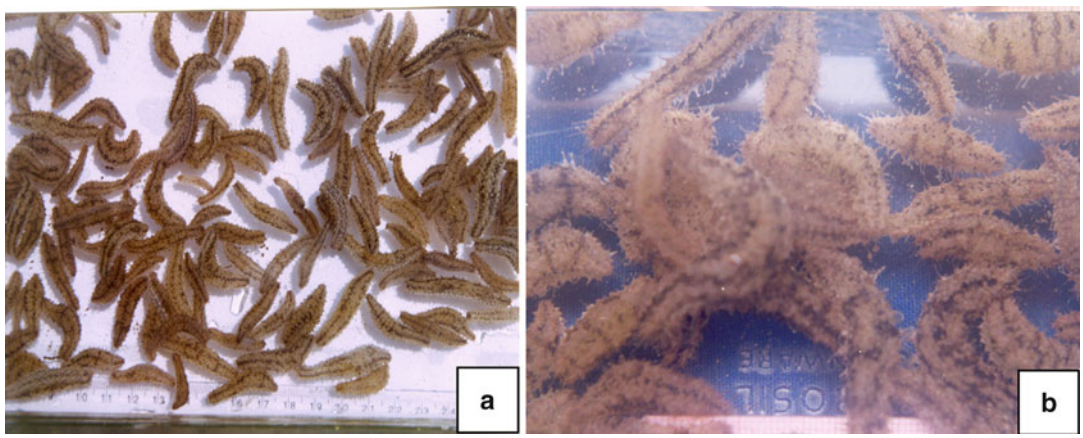

Fig. 3 One-month-old juveniles of sea cucumbers: (**a**) *H. scabra* and (**b**) *H. spinifera*

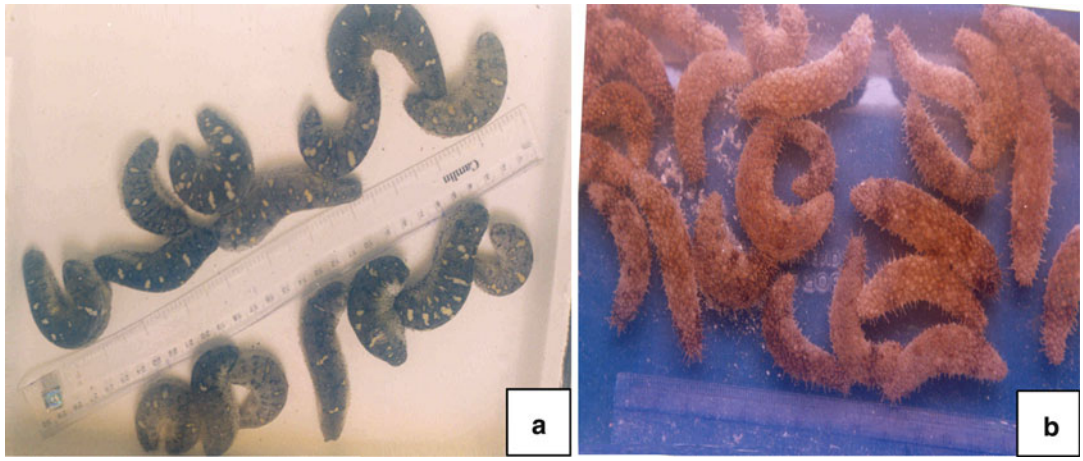

Fig. 4 One-hundred-and-twenty-day-old juveniles of sea cucumbers: (**a**) *H. scabra* and (**b**) *H. spinifera*

juveniles attained an average length of 20 mm, a mixture of *Sargassum* spp. powder and fine sand in a proportion of 1:2 was given at 1 % of the body weight of the juveniles (initially <80; <200 μm as the days progressed) (Asha and Muthiah 2007). Addition of Algamac at 2 % level was provided along with the above feed. Fifty percent water exchange was given daily and the juveniles were taken out using a brush, and the length and number of live juveniles were noted for assessing the growth and survival rate. By maintaining appropriate stocking densities, periodic transferring to new tanks along with size-wise segregation and proper feeding, the growth rate of the juveniles can be improved.

Sea Ranching and Culture

The average size recommended for the release of sea cucumber juveniles to a suitable habitat to replenish the wild population is 20–30 mm. The juveniles of *H. scabra* and *H. spinifera* (Figs. 3b and 4b) produced on several occasions in the hatchery were sea ranched around the Gulf of Mannar area. The culture experiments of juvenile *H. scabra* attempted in a prawn farm using concrete rings yielded encouraging results that indicated their efficiency in cleaning the pond bottom by consuming the feed waste (James et al. 1999). It is advised to stock them at a rate of 30,000 per hectare.

Future Prospects

The continued research effort in the hatchery operation has refined the existing hatchery technology for the mass production of the juvenile *H. scabra* and *H. spinifera*. Future research needs to be focused on the study of the present stock structure of commercial sea cucumbers along the Gulf of Mannar, which is essential to assess the effect of sea ranching in the long run. By upgrading the existing larval and juvenile rearing techniques, cost-effective mass production of holothurian juveniles can be carried out in an effective way which will in turn be helpful in evolving strategies for conservation and sustainable fishery and export of sea cucumbers from India and ultimately will improve the foreign exchange and the economic status of poor fishermen communities along the Gulf of Mannar and Palk Bay area of the southeast coast of India.

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